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Flight Crews & Modern Aircraft: In Search of SA

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Why are we concerned about Situation Awareness?

- **Leading Causal Factor in Review of 175 Military Aviation Mishaps**

  (Hartel, Smith & Prince , 1991)

- **Major Causal Factor in 88% of Accidents Associated with Human Error in Review of Major Aircarrier Accidents (1989-1992)**

  (Endsley, 1994)

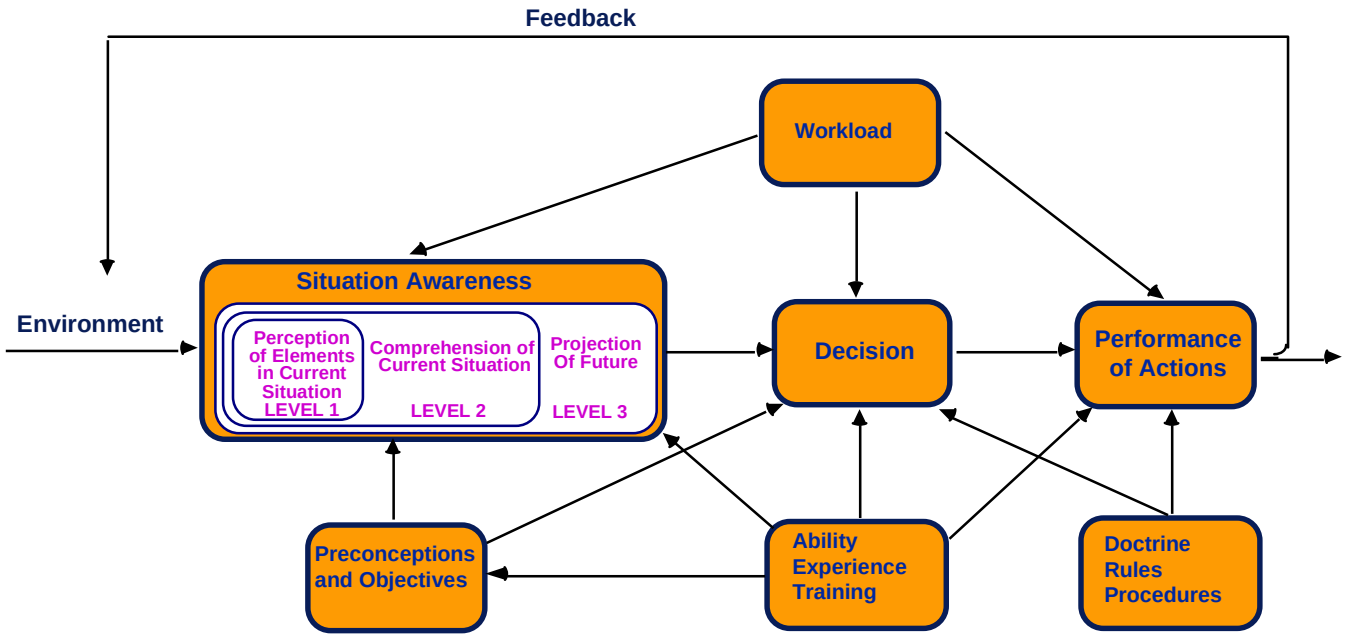
Situation Awareness: Drives the Decision Process

SITUATION AWARENESS | **DECISION MAKING** | **PERFORMANCE**

To improve decision making & performance

Improve SA

What is SA?



Situation Awareness is the Perception of the Elements in the Environment within a Volume of Time and Space, the Comprehension of their Meaning, and the Projection of their Status in the Near Future. (Endsley, 1988)

Elements: Aircraft - General

Geographical SA

- own aircraft
- other aircraft
- terrain features
- airports
- cities
- waypoints
- navigation fixes
- position relative to designated features
- path to desired location
- runway & taxiway assignments
- path to desired location
- climb/descent points

Spatial/Temporal SA

- attitude
- altitude
- heading
- velocity
- vertical velocity
- G's
- flight path
- actual values relative to assigned
- projected flight path
- projected landing time

System SA

- system status
- functioning and settings
  - radio
  - altimeter
  - transponders
  - flight modes & automation
- deviations from correct settings
- ATC communications present
- fuel
- impact of degrades & settings on performance
- time and distance available on fuel

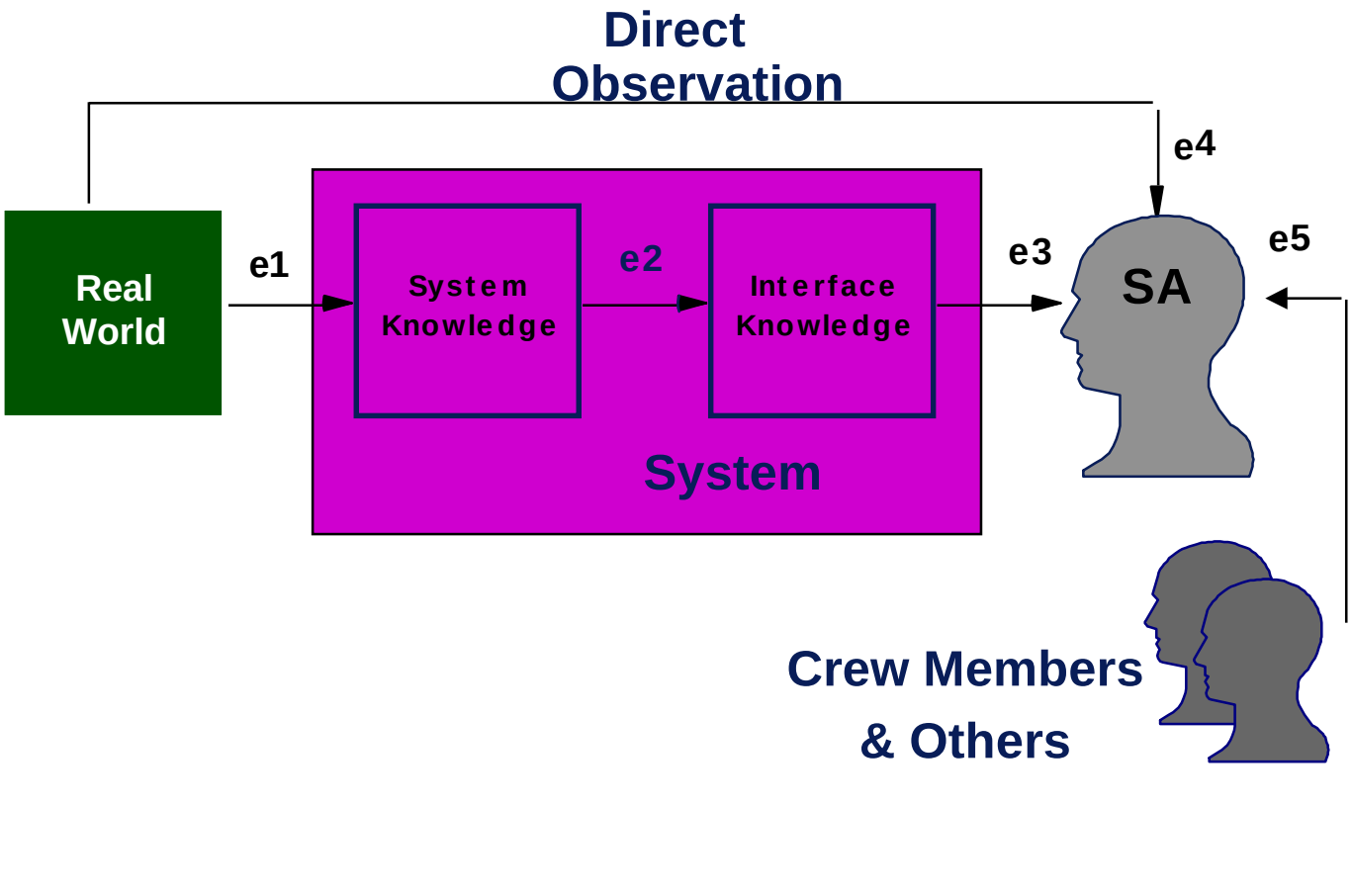
Environmental SA

- weather formations & movement
- temperature
- icing
- ceilings
- fog
- turbulence, winds
- sun
- visibility
- IFR/VFR conditions
- areas to avoid
- flight safety
- projected weather conditions

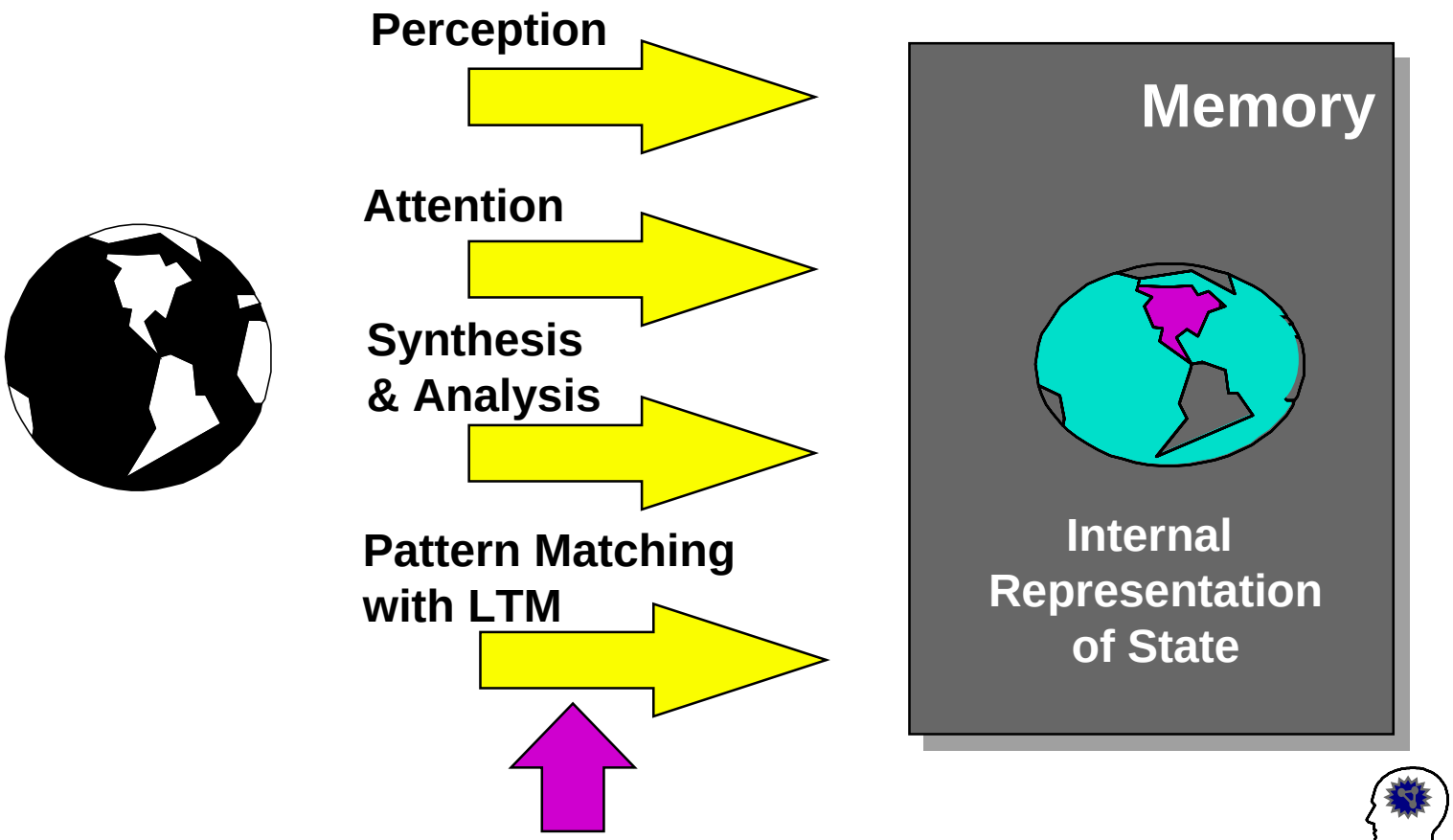
Tactical SA

- identification
- tactical status
- type
- capabilities
- location
- threat flight dynamics
- own capabilities relative to threat
- threat detections
- threat launch capabilities
- threat prioritization
- threat imminence and assignments
- current & projected
  - intentions, tactics,
  - firing, maneuvering
  - mission timing & status
- confidence level of info

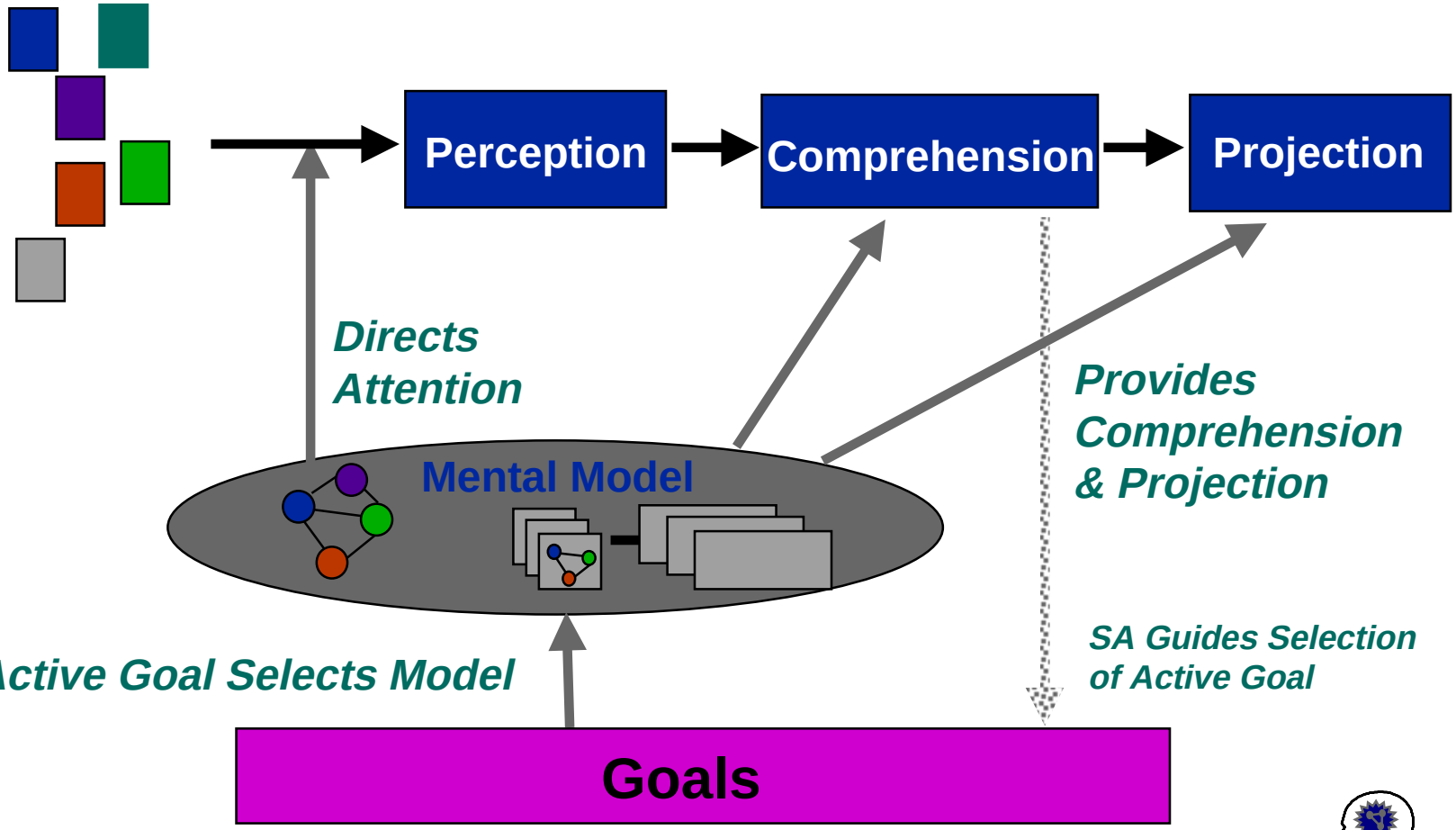
How do we get SA?



Situation Awareness: the Product of the Processes



Mechanisms of SA



Key Features

- **Limited attention and working memory**
  - Novices
  - Novel Situations
- **Expertise**
  - Pattern-matching to schema
    - rapid categorization& comprehension
  - Mental models
    - direct attention
    - provide comprehension & projection
  - Automaticity
    - low attention demand
    - limited awareness of novel cues

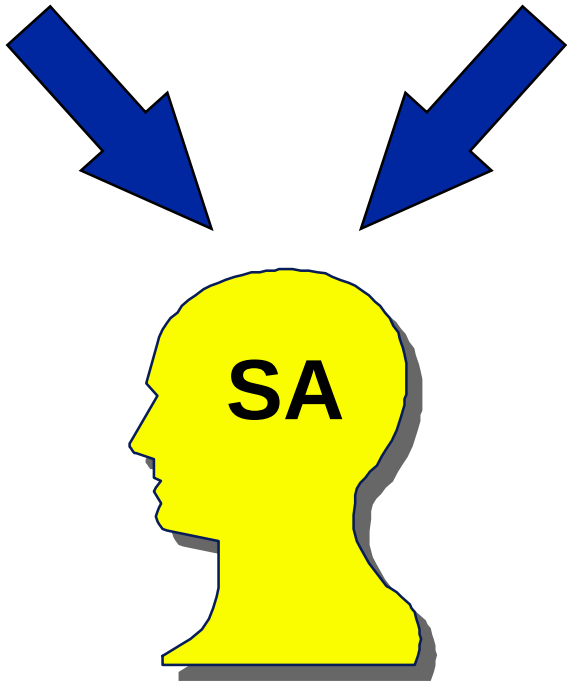
Key Features (con't)

- **Interplay of Data-driven/goal-driven processing**
  - Data driven
    - perceptual salience of cues
    - determines which goals may be most relevant
  - Goal driven
    - directs attention
    - determines interpretation
      - comparison to goal states
      - selects active mental model
  - Constant trade-off between two processing modes
    - dynamic, alternating process

Factors Affecting SA

Individual

Abilities
Knowledge
Skills
Training
Experience



System & Environment

System Capabilities
Interface
Stress/Fatigue
Workload
Complexity
Automation

Glass Cockpit

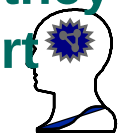
- **Flight Management Systems**
  - **Greatly improved accuracy in navigation**
- **Potential for Catastrophic Errors**
  - **Misprogramming**
  - **Mode errors**
  - **Out-of-the-loop errors**

Problems with Automation

- **1987 - Northwest MD-80**
  - Crashed on takeoff at Detroit -
  - Improper configuration of flaps & slats
  - Failure of automated take-off configuration warning system
  - Crew not aware of state of system or failure of auto
- **1989 - US Air B-737**
  - Crashed on takeoff at LaGuardia
  - Accidental disarming of autothrottle
  - Crew could not gain control of aircraft with mistrimmed rudder
- **1992 - A320**
  - Crashed during non-precision approach at Strasbourg
  - Possible mode awareness error - entering 3300 fpm descent instead of 3.3 degree descent

Impact of Automation on Situation Awareness

- **Out-of-the-loop performance problem**
  - Problem in maintaining awareness of the state of the automation and the state of the system
    - Detection of system failure
    - Developing an understanding of system state
- **Problems in understanding the automation**
  - System complexity
  - Poor mental models
- **Workload Changes**
  - Changes in the level and type of workload
- **Interface Changes**
  - Changes in the types of tasks performed, the way they are performed and the displays provided to support them



The Out-of-the-Loop Performance Problem

- **Loss of Skills**
- **Loss of Situation Awareness**
  - **Vigilance, Complacency & Monitoring**
  - **Change in Feedback**
  - **Active vs. Passive Processing**

Lack of Understanding of Automation

- **What is it doing now?**
- **Why is it doing that?**
- **Well I've never seen that before!**

- **Problems due to**
  - **System complexity**
  - **Poor interface design**
    - **lack of salience of information, mode changes**
  - **Insufficient training**
    - **some modes or circumstances very rare**
    - **inadequate mental models**

Does Automation Reduce Workload?

- **Automation of least use when workload highest**

  (Bainbridge, 1983)

- **Pilots report workload same or higher in critical phases of flight**

  (Wiener, 1985)

- **Initiation of automation when workload is high increases workload**

  (Harris, et al, 1994; Parasuraman, et al, 1994)

- **Elective use of automation not related to workload level of task**

  (Riley, 1994)

- **Subjective workload high under monitoring conditions**

  (Warm, et al, 1994)

Impact of Automation on SA in the FMS Cockpit: The Accident at Cali

- **Flight**
  - **B 757**
  - **1-1/2 hour delay leaving Miami**
  - **Highly experienced crew**
    - **First Officer Flying**
    - **Captain communicating with ATC & operating FMS**
- **Cali airspace - ATC non-radar**
- **Pilots interpreted clearance to Cali VOR as a direct clearance**
  - **Entered direct CLO into the FMS.**
  - **Dropped intermediate fix Tulua VOR**
- **Cali ATC provided different runway & approach**
  - **Crew accepted**

The Accident at Cali

- **Captain asked ATC if they could proceed to Rozo and then execute approach**
  - **ATC: "Affirmative. Take Rozo 1 and runway 19, the wind is calm"**
- **Cockpit crew entered "direct R" into FMS.**
  - **Rozo indicated by identifier R on map**
  - **in FMS database R is Romeo (near Bogota)**
  - **Put plane into left bank away from Cali**
- **Over 1 minute later, crew notices they are off course**
  - **Spent several minutes trying to figure out what happened**
  - **Turned plane back towards desired course to Cali**
- **GPWS warning**

Loss of SA & the FMS

- **Local SA Vs Global SA**
- **False Worlds**
- **Vertical Vs Lateral Flight Path Display**
- **FMS Programming**
- **Supervisory Control, Trust & Monitoring**

Local SA Vs Global SA

- **FMS designed for good Local SA**
  - **Local SA - supports one goal**
    - **Provides clear, accurate flight path**
- **Does not support Global SA**
  - **Global SA - supports understanding across goals**
    - **Which goals should be active**
    - **Rapid goal switching**
  - **FMS display did not support the global SA needed to**
    - **Determine location relevant to pertinent landmarks**
    - **Rapidly change goals (programming in a new flight path).**

False Worlds

- **Easy to create own "map of the world"**
  - FMS displays points entered & magenta line flight path
    - Programming errors
      - wrong routes
      - unsafe routes
- **Check against reality?**
  - Paper map
    - Nomenclature not consistent between FMS & maps
      - CF19 & FF19
      - D16 & D21
  - Coordination time consuming and error prone
    - FMS highly salient
    - Non-integrated source likely to be ignored under time pressure & stress

Vertical Vs Lateral

- **FMS provides clear lateral flight path information**
- **Vertical path not directly portrayed**
  - **Can get altitudes of some points**
- **No vertical terrain information**
  - **Cannot directly see relation between aircraft altitude and terrain features**
- **In accident**
  - **Pilots resolved lateral problem**
    - **Brought aircraft back towards correct course**
  - **Did not have SA of vertical situation**
    - **Continued descending**
    - **Were aware of altitude**
    - **No indication they had any idea of proximity to terrain**

FMS Programming

- **Desired path must be programmed**
  - **Usually on ground**
- **Inflight changes must be reprogrammed**
  - **Route changes**
  - **Runway changes**
    - **time pressure**
      - **find, review charts**
      - **reprogram route (many steps)**
    - **errors easy**
- **Compounded by inconsistency between naming conventions used for maps (ICAO) and FMS database (ARINC 424)**

Supervisory Control, Trust, &Monitoring

- **Fly through programming the FMS**
  - Supervisory Control
- **Complacency & trust**
  - Failure to monitor aircraft as it went off course
  - Busy with other tasks
- **Out-of-the-loop performance problems**
  - Took several minutes in trying to understand what the automation was doing when they noticed they were off course
  - Loss of level 2 SA - understanding
- **Automation Fixation**
  - Keep at it until you make it work
  - When do you quit and fly manually?

Recommendations

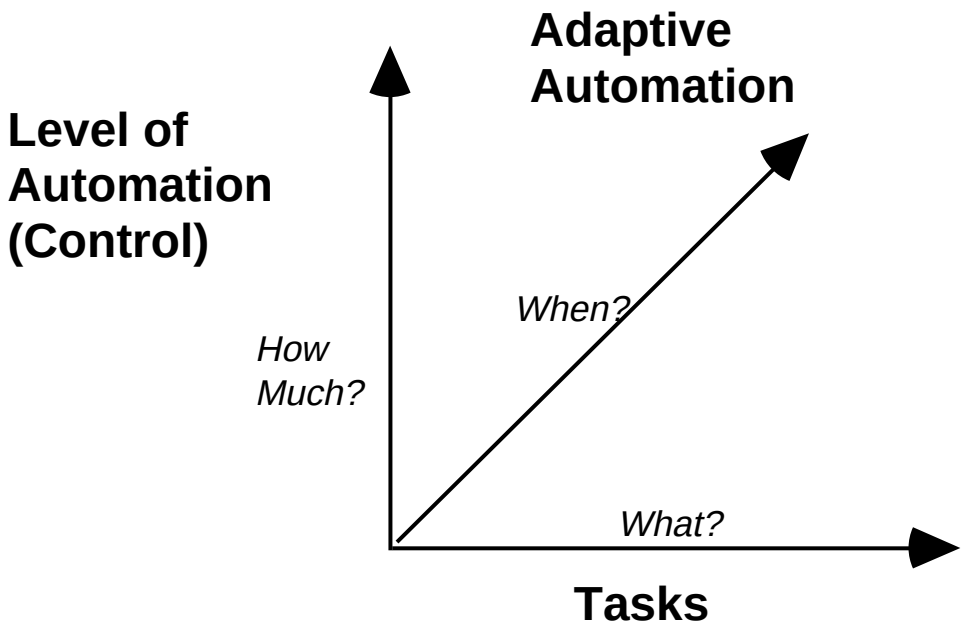
- **FMS displays need to provide single, integrated source of information**
  - **Lateral & vertical**
  - **support global SA**
  - **provide reality check**
- **Reprogramming in critical phases of flight needs to be eliminated or greatly simplified**
- **More emphasis is needed to train pilots to recognize when to shift to lower levels of automation**

When is performance good?

Humans involved in tasks,
aware of situation
but not overloaded

Traditional automation approaches focus on overload problem without taking into account involvement & awareness

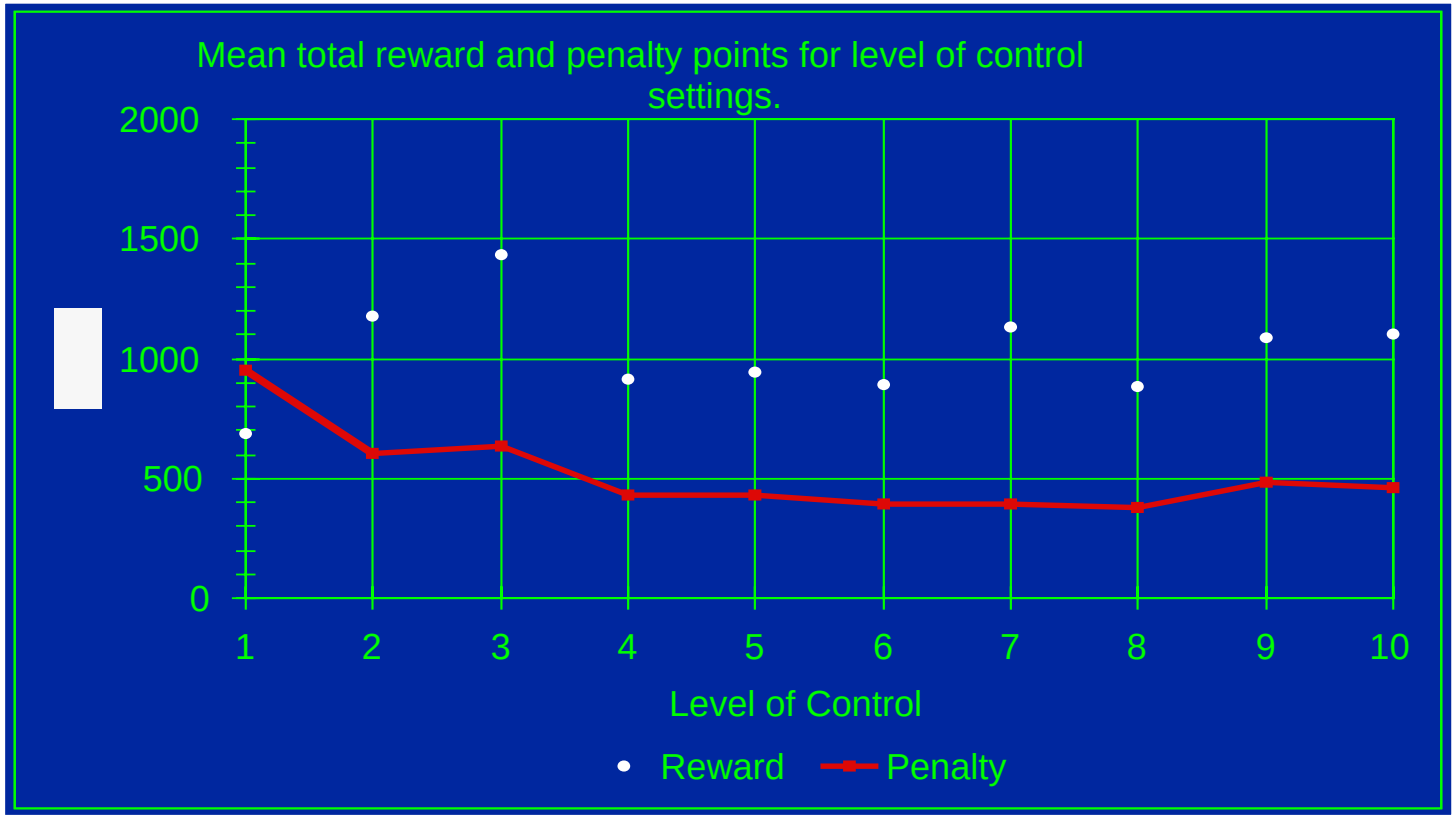
Automation Implementation



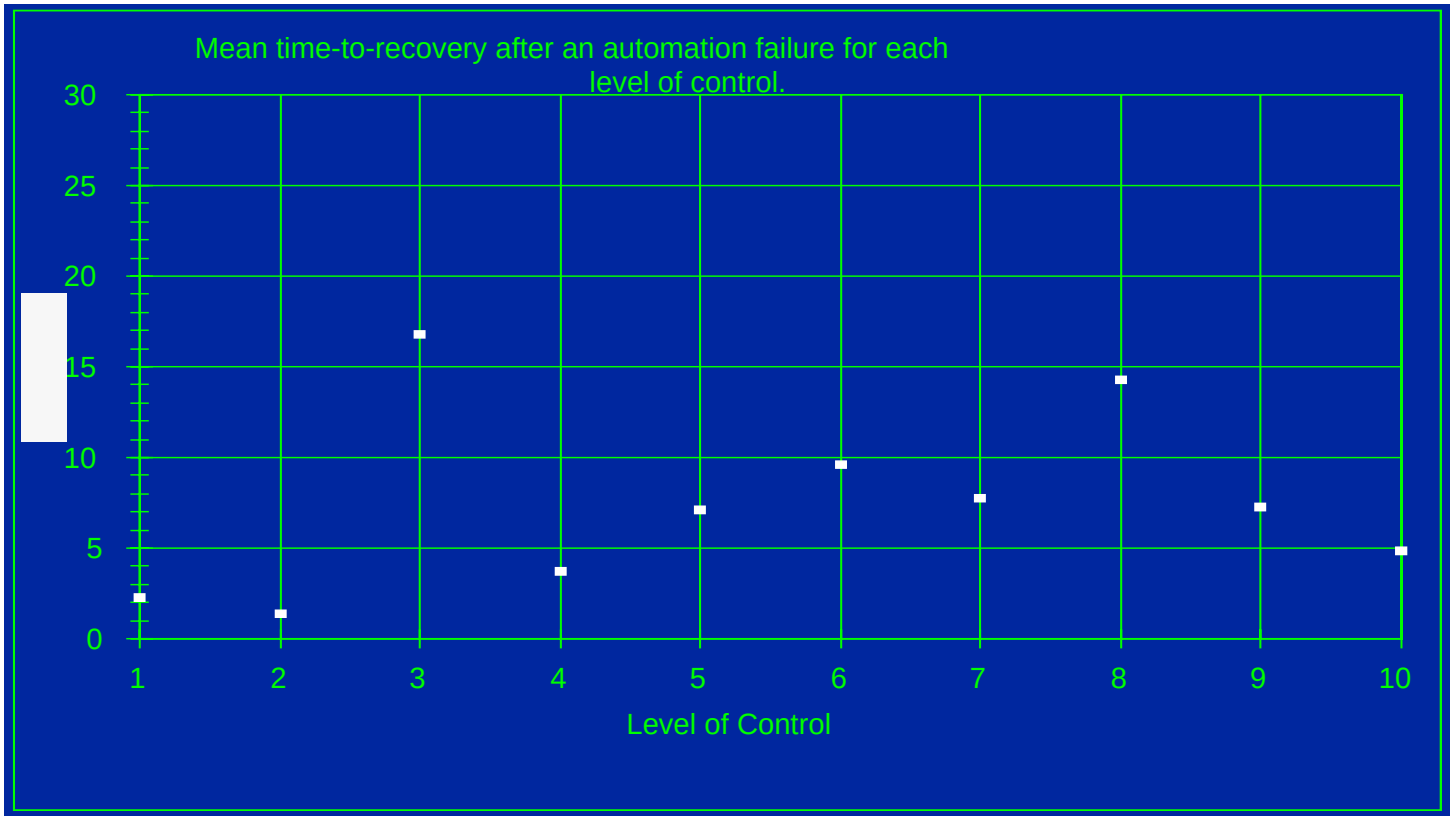
Taxonomy of Levels of Automation

	ROLES			
LEVEL OF CONTROL (LOC)	MONITORING	GENERATING	SELECTING	IMPLEMENTIN
(1) Manual Control (MC)	Human	Human	Human	Human
(2) Action Support (AS)	Human/Compute	Human	Human	Human/Compute
(3) Batch Processing (BP)	Human/Compute	Human	Human	Computer
(4) Shared control (SHC)	Human/Compute	Human/Compute	Human	Human/Compute
(5) Decision Support (DS)	Human/Compute	Human/Compute	Human	Computer
(6) Blended Decision Making (BDM	Human/Compute	Human/Compute	Human/Compute	Computer
(7) Rigid System (RS)	Human/Compute	Computer	Human	Computer
(8) Automated Decision Making (A	Human/Compute	Human/Compute	Computer	Computer
(9) Supervisory Control (SC)	Human/Compute	Computer	Computer	Computer
(10) Full Automation (FA)	Computer	Computer	Computer	Computer

Performance Under Normal Operating Conditions



Performance During Automation Failure



Results of Research on Effect of Levels of Automation

- **Under Normal Conditions**
  - **Human performance aided by automation of *implementation* portion of tasks**
  - **Hindered by automation that assists in *strategy generation* (e.g. decision support systems)**
- **Under Automation Failure Conditions**
  - **Humans slowest to recover when advanced queuing of tasks provided (most out-of-the-loop)**

Conclusions

- **Automation in the cockpit can affect SA in many ways**
  - **Required vigilance & monitoring may increase workload**
  - **Changes in system interface may not support SA needs**
  - **Change in type of tasks from doing to programming**
    - **Can lead to new types of error**
    - **Out-of-the loop problems**
- **Critical to create good mental models of how the automation works**
  - **More training may be needed**
- **Look for technologies that enhance SA**
  - **Need better information easier**